NON-INVASIVE CHARACTERIZATION OF SMALL-SCALE PATTERNS OF BENTHIC BIOGENIC STRUCTURE BY ULTRASOUND: INFAUNAL DYNAMICS AND SEDIMENT STRUCTURE, AND EFFECT OF SEDIMENT DISTURBANCE

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Award # N00014-96-1-0374

LONG TERM GOALS:

Our goal is to examine how temporal changes in marine, soft-sediment infaunal density, distribution and species composition affects sediment surface roughness and below-surface structure. The use of commercial ultrasonic sensors allows us to examine temporal patterns in biogenic structure and roughness on fine spatial scales (mm) without invasive disturbance. In addition, we are examining how physical disturbance of the sediment affects biogenic structure, both above and below the sediment surface, and determining whether disturbed sediments exhibit a "signature" in terms of patterns of biogenic structure.

OBJECTIVES:

Our major objectives are twofold: 1) How does biogenic structure at and below the sediment surface change in sediment assemblages under controlled conditions? What is the temporal persistence of relict biogenic structure under undisturbed conditions?; and 2) How does biogenic structure respond to different frequencies of physical sediment disturbance under controlled conditions? Does physical sediment disturbance leave a "signature" in terms of biogenic structure? This work is supported by ONR Biological Oceanography.

APPROACH:

We possess 16 flow-through chambers (120 X 14 X 27 cm) which allow maintenance of benthic assemblages from both nearshore and continental shelf habitats for extended

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Non-invasive Chracterization of Small-scale Patterns of Benthic Biogenic Structure by Ultrasound: Infaunal Dynamics and Sediment Structure, and Effect of Sediment Disturbance**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Rhode Island,Graduate School of Oceanography,Narragansett,RI,02882**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

periods under controlled conditions. The 16 chambers are connected to a headtank that continuously receives seawater pumped from Narragansett Bay, RI. The water in the headtank is temperature-controlled to not exceed 15°C.

The general experimental approach is to collect sediment in the field, transport it back to the laboratory, add it to the experimental chambers, and then manipulate and image the sediment structure as required. Imaging is conducted with an ALOKA SSD 500 ultrasound machine (purchased with a previous ONR grant to Carey et al. at URI) or with a Toshiba Eccocee 300 color Doppler unit (purchased from this grant). The acquisition of the color Doppler unit expands our capabilities greatly by allowing real-time measurement of flow concurrently with the sediment imaging. We have used 7.5 MHz probes for our current imaging because of the high resolution coupled with adequate sediment penetration (4 cm). The probes are mounted parallel to the sediment surface and moved in known 3-D space using a macropositioning system constructed from optical rails. We can then relate the ultrasound images to 3-D space in the flow chambers. The ultrasound images are captured on videotape and then ported to a PC with a PCI-bus video capture card for subsequent software-based enhancement and image processing. With appropriate macro scripts written in Matlab,, we can then produce a 3-dimensional map (areal and with depth in the sediment) of biogenic structure in our chambers.

WORK COMPLETED:

1) Experimental study to examine Objective #2.

Sediments for the second set of experiments (Objective #2) were collected in June, 1997. Sediment was collected by Van Veen grab from a depositional silt-clay basin (7 m depth) in Narragansett Bay. The faunal assemblage is dominated by the polychaete *Mediomastus ambiseta* and the bivalve *Nucula annulata*. Sediment was also collected from a sandy silt-clay station (37 m depth) in Rhode Island Sound where the infauna is dominated by suspension-feeding sabellid polychaetes and the deposit-feeding polychaetes *Cossura longocirrata* and *Paraonis gracilis*. Enough sediment was collected from each station to fill 8 chambers to a depth of 15 cm (16 chambers total). After stabilization (4 weeks), ultrasound images were collected in 56 cm long strips at 1 cm intervals across the width of each chamber at biweekly intervals for 13 weeks. Three treatments (frequencies of disturbance) were employed in this experiment. Disturbance levels were 1) only at the start of the experiment, 2) monthly (3 times during the experiment), and 3) weekly. The disturbance was the raking of the sediment to a depth of 2 cm. All images are archived on videotape and post-capture processing is ongoing.

2) Analysis and post-capture processing of images collected to examine Objectives # 1 & 2.

With the assistance of graduate student Robert Griffin, technician Gwynne Holcombe and Kelly McDonnell (URI Coastal Fellow), we have continued to refine procedures for the analysis of the archived ultrasound images. Over the last year, we have developed a MATLAB script to automatically (upon program opening) detect the sediment surface on

an ultrasound image by detecting varying levels of pixel intensity in the image. This allows rapid analysis of surface features at sub-mm horizontal resolution. Analysis of sub-surface structures remains time-consuming at this juncture because of the difficulty in resolving these structures based on pixel intensity. Analysis still requires biological intuition and sharp eyes.

All ultrasound images from the experiment designed to examine Objective # 1 (FY 1996) have been ported to computer and description of surface features has been completed. Tapes have been ported at biweekly compared to weekly intervals because of the sheer volume of data to be processed. Analysis of subsurface features is still continuing. Images from the experiment designed to examine Objective # 2 (FY 1997; experiment was terminated in October, 1997) are currently in the process of being transferred from videotape to computer for further analysis.

RESULTS:

Analysis of the image series are still progressing, but patterns in biogenic structure (e.g. tubes) from the initial (FY 1996) experiment appear to be stationary on the order of 1-2 weeks. However, even in the absence of physical disturbance, sharp discontinuities in spatial pattern occur at this time scale rather than the appearance of gradual changes. Patch structure is sharply dynamic and is often not a function of the gradual blending together of existing spatial structure. This is supported by our results showing that some structural features change more at hourly intervals than at weekly intervals (a temporal smoothing). These results have serious implications for the temporal scale of analysis of infaunal spatial patterns and effects of bioturbation on benthic processes.

The development of the MATLAB macro to automatically detect the sediment surface in the ultrasound images has dramatically speeded up image processing. With this development, we will be able to rapidly process the FY 1997 experimental data. Our initial observations of sediment structure at different frequencies of disturbance indicate that there is an effect of disturbance frequency on surficial patterns of structure.

IMPACT:

This research will provide new information on temporal changes in small-scale patterns of benthic biogenic structure and infaunal patch dynamics, as our results to date indicate. Also, we will be able to examine the structural signal of disturbed sediments and infaunal responses to disturbance in a way never performed before. Studies on temporal patterns in biogenic structure and patch dynamics have been severely hampered by the inability to sample without disturbing the sediment. The use of ultrasound technology allows us to make a major breakthrough in the analysis of sediment systems.

TRANSITIONS:

Both Year 1 and 2 tasks and goals have been achieved or are proceeding on schedule. We anticipate that further data processing will take us easily to the June 30, 1998 end-date of the project. The potential field deployment of ultrasonic sensors is of great interest as a potential transition, and informal discussion has ensued with members of the Ocean Engineering Faculty here at URI. The engineers believe field deployment after modification is feasible.

RELATIONSHIP TO OTHER PROJECTS:

Significant graduate student interest has been expressed in using the ultrasound equipment for analysis of faunal feeding dynamics and geotechnical sediment property changes. We expect more graduate student involvement in the future. Because of our flow measurement (Doppler) capabilities, we are also planning on extending our research to examine fine-scale particle trajectories around sedimentary biogenic structure. The Doppler system has been used heavily by students of T. Hara's, who are evaluating it's potential in the analysis of dense, fluidized sediment flows. In addition, we have had enquiries from European scientists on the feasibility of using ultrasound in some benthic experiments (bioturbation rates) planned for the near future.